SMPTE Standard for television— signal parameters— 1125/60 high-definition production system

1. Scope

This standard defines the basic characteristics of the video signals associated with origination equipment operating in the 1125/60 high-definition television production system. As this standard deals with basic system characteristics, all parameters are untoleranced.

2. Scanning Parameters

The video signals represent a scanned raster with the following characteristics:

Total scan lines per frame	1125
Active lines per frame	1035
Scanning format	Interlaced 2:1
Aspect ratio	16:9
Field repetition rate	60.00 Hz
Line repetition rate (derived)	33750 Hz

3. System Colorimetry

The system is intended to create a metameric reproduction (visual color match) of the original scene under conditions of equal color temperature and luminance between the original scene and its reproduction. To this end, the combination of a camera's optical spectral analysis and linear signal matrixing shall match the CIE color-matching functions (1931) of the reference primaries. Further, the combination of a reproducer's linear matrixing and reproducing primaries shall be equivalent to the reference primaries. (See Appendix A1.)

Colorimetric analysis and signal amplitude transfer function are defined in the following sections:

3.1 Chromaticity of Reference Primaries:

G: $x = 0.310$ $y = 0.595$
B: $x = 0.155$ $y = 0.070$
R: $x = 0.630$ $y = 0.340$

where

x and y are CIE 1931 chromaticity coordinates.

3.2 Reference White. The system reference white is an illuminant which causes equal primary signals to be produced by the reference camera, and which is produced by the reference reproducer when driven by equal primary signals. For this system, the reference white is specified in terms of its 1931 CIE chromaticity coordinates, which have been chosen to match those of CIE illuminant D_{65}:

$x = 0.3127$ $y = 0.3291$

3.3 Opto-Electronic Transfer Characteristic of Reference Camera:

$$V_c = 1.1115 \times L_c^{(0.45)} - 0.1115 \quad \text{for } L_c \geq 0.0228$$
$$V_c = 4.0 \times L_c \quad \text{for } L_c < 0.0228$$

where

V_c is the video signal output of the reference camera normalized to the system reference white, and L_c is the light input to the reference camera normalized to the system reference white.

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3.4 Electro-Optical Transfer Characteristic of Reference Producer:

$$L_r = [(V_r + 0.1115)/1.1115]^{(1/0.45)} \quad \text{for } V_r \geq 0.0913$$

$$L_r = V_r/4.0 \quad \text{for } V_r < 0.0913$$

where

V_r is the video signal level driving the reference reproducer normalized to the system reference white, and L_r is the light output from the reference reproducer normalized to the system reference white.

4. Reference Clock

Signal durations and timings are specified both in microseconds and in reference clock periods:

Reference clock periods in total line: 2200
Reference clock frequency (derived): 74.25 MHz

5. Video Signal Definitions

The image is represented by three parallel, time-coincident video signals. Each incorporates a synchronizing waveform. The signals shall be either of the following sets:

Color Set	Color Difference Set
E_G' — green	E_Y' — luminance
E_B' — blue	E_{PB}' — blue color difference
E_R' — red	E_{PR}' — red color difference

where

$[E_G'\ E_B'\ E_R']$ are the signals appropriate to directly drive the primaries of the reference reproducer (being non-linearly related to light levels as specified in Secs. 3.3 and 3.4), and $[E_Y'\ E_{PB}'\ E_{PR}']$ can be derived from $[E_G'\ E_B'\ E_R']$ through a linear matrix.

Specifically,

$$E_Y' = (0.701 \times E_G') + (0.087 \times E_B') + (0.212 \times E_R')$$

E_{PB}' is amplitude-scaled (E_B'-E_Y'), according to

$$E_{PB}' = \frac{(E_B'-E_Y')}{1.826}$$

and E_{PR}' is amplitude-scaled (R-Y), according to

$$E_{PR}' = \frac{(E_R'-E_Y')}{1.576}$$

where the scaling factors are derived from the signal levels given in Sec. 6.3, and the transformation equations which follow.

The derived transformation between the two sets is

$$\begin{bmatrix} E_G \\ E_B \\ E_R \end{bmatrix} = \begin{bmatrix} 1.000 & -0.227 & -0.477 \\ 1.000 & 1.826 & 0.000 \\ 1.000 & 0.000 & 1.576 \end{bmatrix} \begin{bmatrix} E_Y \\ E_{PB} \\ E_{PR} \end{bmatrix}$$

$$\begin{bmatrix} E_Y \\ E_{PB} \\ E_{PR} \end{bmatrix} = \begin{bmatrix} 0.701 & 0.087 & 0.212 \\ -0.384 & 0.500 & -0.116 \\ -0.445 & -0.055 & 0.500 \end{bmatrix} \begin{bmatrix} E_G \\ E_B \\ E_R \end{bmatrix}$$

6. Video and Synchronizing Signal Waveforms

The combined video and synchronizing signal shall be as shown in Fig. 1. For illustrative purposes, a video signal of the form E_Y', E_G', E_B', or E_R' is shown. The details of the synchronizing signal are identical for the E_{PB}' and E_{PR}' color-difference signals.

6.1 Timing

6.1.1 The timing of events within a horizontal line of video is illustrated in Fig. 1(a) and summarized in Table 1. All event times are specified, in terms of the reference clock period, at the midpoint of the indicated transition.

Table 1
Timing of Events of a Video Line

	Reference Clock Periods
Rising edge of sync (timing reference)	0
Trailing edge of sync	44
Start of active video	192
End of active video	2112
Leading edge of sync	2156

6.1.2 The durations of the various portions of the video and sync waveforms are illustrated in Fig. 1 (b), (c), and (d), and summarized in Table 2.

Table 2
Duration of Video and Sync Waveforms

	Reference Clock Periods	Time (Derived) (μsec)
a	44	0.593
b	88	1.185
c	44	0.593
d	132	1.778
e	192	2.586
f (Sync rise time)	4	0.054
Total line	2200	29.63
Active line	1920	25.86

6.2 Bandwidth

6.2.1 The color set [E_G' E_B' E_R'] comprises three equal-bandwidth signals whose nominal bandwidth is 30 MHz.

6.2.2 The color difference set [E_Y' E_{PB}' E_{PR}'] comprises a luminance signal E_Y' whose nominal bandwidth is 30 MHz, and color difference signals E_{PB}' and E_{PR}' whose nominal bandwidth is 30 MHz for analog originating equipment, and 15 MHz for digital originating equipment.

6.3 Analog Representation. The video signals are represented in analog form as follows:

		E_Y', E_G', E_B', E_R' Signals
Reference black level	(mV)	0
Reference white level	(mV)	700
Synchronizing level	(mV)	±300

		E_{PB}', E_{PR}' Signals
Reference zero signal level	(mV)	0
Reference peak levels	(mV)	±350
Synchronizing level	(mV)	±300

Appendix

(This Appendix is not part of the SMPTE Standard, but is included for information only.)

A1. System Colorimetry

The parameter values in Sec. 3 are based on current practice and technical constraints. It is recognized that the availability of a wider color gamut is highly desirable in an originating system. Furthermore, it is useful, for purposes of picture processing, to have available video signals proportional to light levels. In particular, the encoding of linear signals, commonly identified as a "constant-luminance" system, is believed to be desirable.

In order to achieve a practical implementation of these desirable characteristics, it is necessary to incorporate non-linear processing (according to the equations of Sec. 3) at various points in the system, within the originating production plant, along the distribution chain, and within the home receiver.

It has not yet been demonstrated that this processing can be achieved with an appropriate balance of precision and cost. Further study of this matter is required in order to demonstrate the feasibility of incorporating such signal processing into commercial equipment where appropriate.

With respect to color gamut, it is felt that the system should embrace a gamut at least as large as that represented by the following primaries:

G:	$x = 0.210$	$y = 0.710$
B:	$x = 0.150$	$y = 0.060$
R:	$x = 0.670$	$y = 0.330$

A2. Digital Representation

It will be necessary to define the digital representation of the 1125/60 HDTV signal. Current practice and experience have not clarified the most suitable value for certain parameters, in particular, the number of bits per sample and the coding law. An appropriate form for the specifications would be the following:

		E_Y', E_G', E_B', E_R' Signals	E_{PB}', E_{PR}' Signals
Quantization	(bits)	[ ]	[ ]
Coding law		[ ]	[ ]
Sampling frequency	(MHz)	74.25	37.125
Samples per active line		1920	960

The sampling structure is orthogonal; line, field, and frame repetitive.

A3. Tolerances

A3.1 Parameter Aim Points. Tolerances are not affixed to any of the parameters specified in this document since it specifies aim points for system design rather than detailed system specifications. Furthermore, it was not possible to determine comprehensive tolerances for all parameters on the basis of current information. It was concluded that tolerancing should be left to future documents which give detailed specifications for specific components or equipment operating in the 1125/60 HDTV system.

Figure 1(a). Timing of events within a video line

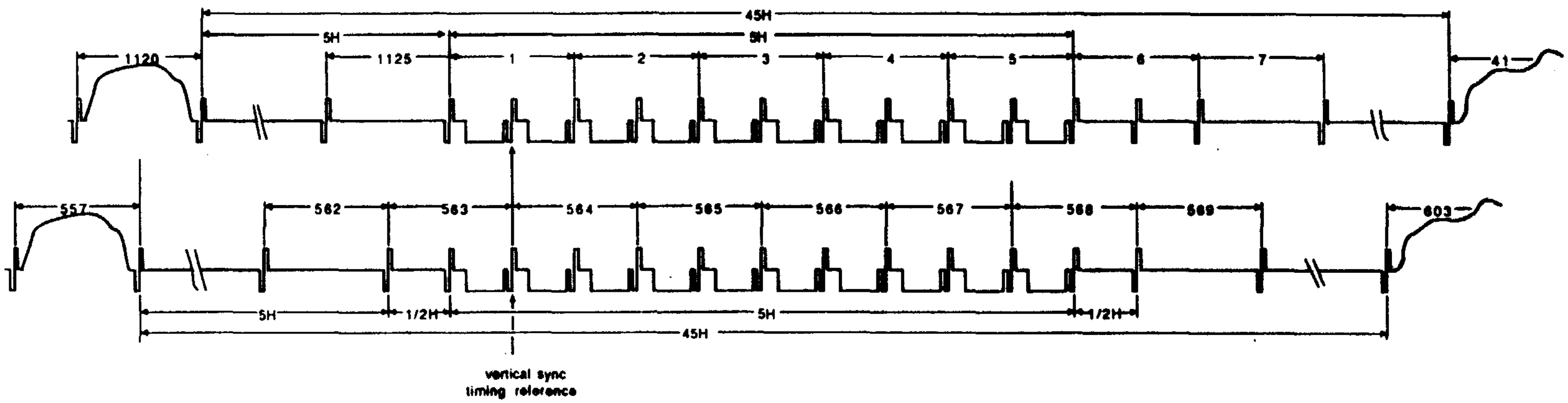

Figure 1(b). Detail of field blanking periods

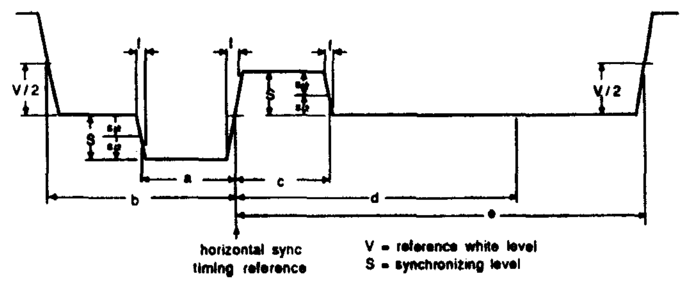

Figure 1(c). Detail of line blanking period

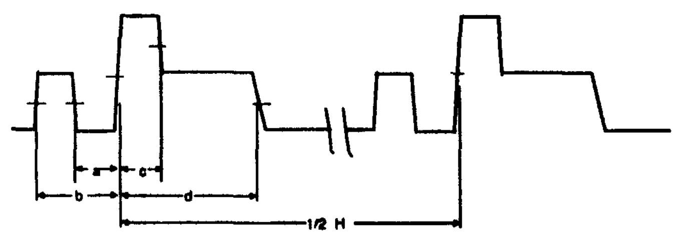

Figure 1(d). Detail of field synchronizing pulse

Fig. 1
Timing, Blanking and Synchronizing Waveforms

A3.2 Line Repetition Rate. Initially, a tolerance was specified for this parameter, to serve as a fundamental tolerance on all system timing. This tolerance was moved to the Appendix to leave the standard untoleranced. The stated value, with tolerance, is:

Line repetition rate (derived) 33750.00 Hz ± 10 ppm

A3.3 Synchronizing Signal. The synchronizing signal specified in this standard is based on time durations, which are toleranced. For the purposes of this standard, counts of reference clock periods were chosen as the primary time specification, and time durations in microseconds are given as derived, quoting no tolerances. For information, the original tolerances on these parameters are:

a		0.593 ± 0.040 μsec
b		1.185 ± 0.040 μsec
c		0.593 ± 0.040 μsec
d		1.778 ± 0.040 μsec
e		2.586 ± 0.040 μsec
f	(sync rise time)	0.054 ± 0.020 μsec
S	sync pulse amplitude	300 ± 6 mV
	amplitude difference between positive and negative-going sync pulses	<6 mV

A4. *Relationships Between Basic and Derived Parameters*

Certain parameters have been determined as basic and fundamental system parameters. The values of all other system parameters can be derived from those chosen as basic. The purpose of this Appendix is to describe and define the derivations.

Line Repetition Rate (L):

$L = S \times F/2$

where

F = field repetition rate (Sec. 2),
and S = total scan lines per frame (Sec. 2).

Reference Clock Frequency (C):

$C = L \times R$

where

L = line repetition rate (Sec. 2, derived above), and R = reference clock periods in total line (Sec. 4).

Transformation Matrices Between Component Sets (Sec. 5):

The transformation matrices can be calculated from the chromaticity coordinates of the reproducer primaries and the chromaticity of reference white (i.e., the color reproduced when the reference reproducer is driven by equal primary signals), according to well-known methods.

Stated briefly, the equation for Y can be found as follows:

$$Y = (G \times J_g \times y_g) + (B \times J_b \times y_b) + (R \times J_r \times y_r)$$

where

J_g, J_b, and J_r are derived as follows:

$$\begin{bmatrix} J_r \\ J_g \\ J_b \end{bmatrix} = \begin{bmatrix} x_r & x_g & x_b \\ y_r & y_g & y_b \\ z_r & z_g & z_b \end{bmatrix}^{-1} \begin{bmatrix} x_w/y_w \\ 1 \\ z_w/y_w \end{bmatrix}$$

and

x_r, y_r, z_r are the chromaticity coordinates of the red primary,

x_g, y_g, z_g are the chromaticity coordinates of the green primary,

x_b, y_b, z_b are the chromaticity coordinates of the blue primary,

x_w, y_w, z_w are the chromaticity coordinates of reference white.